# Permitting CNG and LNG Stations

# Best Practices Guide for Host Sites and Local Permitting Authorities

*Prepared for*

# The California Statewide Alternative Fuel and Fleets Project

***By***

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## 1. Introduction

There are many reasons to convert to natural gas as a transportation fuel:

- Natural gas is **abundant**—with the new techniques to extract gas from shale, the U.S. is now estimated to have at least a 90 year supply of natural gas.
- Natural gas is **cheap**—natural gas will be significantly less expensive than diesel or gasoline and expected to stay that way for the foreseeable future
- Natural gas is **clean**—natural gas is less polluting than diesel or gasoline—about 28 % less carbon intensive with lower NOx and PM[1]
- Natural gas vehicles are becoming **mainstream**--Over the past two decades, natural gas engines have been proven in many fleet applications such as refuse vehicles, urban transit buses, school buses and passenger vehicles
- Natural gas is a good **feedstock** for producing **hydrogen** for fuel cells—a hydrogen powered fuel cell is the "gold standard" for low carbon fuels and natural gas is an excellent source of hydrogen

In some cases, the transition to natural gas may be driven by regulatory requirements to reduce carbon emissions or comply with specific legislation or regulation from local air districts or the California Air Resources Board (CARB).

In conjunction with evaluating the economic and air quality benefits of natural gas, end-users must take into consideration the availability and cost of fueling infrastructure for vehicles operating on compressed natural gas (CNG) or liquefied natural gas (LNG). The purpose of this Guide is to two-fold: 1. To provide those agencies and businesses considering natural gas fueling infrastructure the tools to plan, design, permit, build and operate a compressed natural gas fueling station. 2. To provide local authorities information to properly evaluate proposed CNG or LNG fueling installations.

## 2. CNG and LNG

CNG

Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG) are both gaseous fuels composed primarily of methane, but they differ from each other and from diesel or gasoline. Natural gas is primarily composed of methane (88 to 93 percent) but it also contains a number of other components in smaller quantities, including ethane, propane, butane and inert gases. In its natural state, natural gas is non-corrosive, colorless and odorless. Natural gas is also an asphyxiant and, in sufficient quantities, can cause suffocation.

Natural gas may also contain water (measured in millions of parts per cubic foot) and foreign material such as scale from transportation pipelines. Since both of these materials could harm engines, dessicant

[1] http://www.arb.ca.gov/regact/2009/lcfs09/lcfscombofinal.pdf, p. 49

dryers that remove moisture are typically standard equipment in CNG fueling stations. Filters may also be added to remove other impurities.

Natural gas is highly combustible at low levels of concentration (4 to 16 percent of volume) and burns with a blue flame. Because it is lighter than air, whenever there is a release of gas it quickly dissipates into the air. Based on the National Fire Protection Act Section 49, Appendix B (NFPA), natural gas is classified as extremely hazardous for flammability, slightly hazardous for health and non hazardous in terms of reactivity.

The amount of an explosive gas in a given volume of air is measured by the Lower Explosion Limit (LEL) and the Upper Explosion Limit. For natural gas the lower explosion limit is 5% by volume and the upper limit is 15% by volume. To avoid concentration of natural gas above safe levels, venting and pressure relief devices are required, as well as methane gas detection systems. As an additional safety measure, mercaptan is added as an odorant in the gas utility transmission pipeline so that leaks can be detected. The mercaptan creates the distinctive odor we associate with a gas leak. Facilities where natural gas is being used (for example natural gas vehicle maintenance and repair facilities) must meet stringent building code standards for explosion proofing, fire proofing and air circulation.

Natural gas does not liquefy under pressure alone, but any releases of pressurized gases are quite loud and can be very dangerous. For example a pressurized hose that has a gas release can whip around and cause great bodily injury or property damage. Flames must be extinguished with carbon dioxide, dry chemicals or halo carbon.

Natural gas is transported from the well to the gas utility in underground transmission pipelines that flow at 150 to 450 pounds per square inch gauge (psig). At the distribution level the pressure is reduced to 15 to 45 psig. The gas dispensed to customers is measured by the local utility using a Meter Set Assembly or MSA which serves as the meter and cash register for the utility. An emergency gas supply shutoff is also installed at the MSA in case of an earthquake or other catastrophic event. A potential fueling station owner should find out the inlet pressure at the point of connection to determine if the site is a feasible location.

Home natural gas pressure is very low and is measured in “inches on the water column” which is less than one pound per square inch. This pressure level is adequate for cooking and heating or cooling and can even be used for a vehicle refueling appliance. Devices such as the BRC home refueling product provide an overnight fueling solution. Commercial stations require much higher inlet pressures—typically a minimum 14.5 pounds per square inch (also known as a bar).

At a CNG fueling station, gas is taken at inlet pressure and compressed to 3600 to 5500 psi. The gas may be dispensed directly from the compressor to the vehicle through a fueling hose (buffer storage) or stored in large high pressure vessels (cascade storage). The duty cycle of the station over a 24 hour period (i.e, is there a peak demand period, then a lull or a steady flow of vehicles) will determine whether direct fill or storage is the best solution for the station owner.

Storage vessels for cascade storage are typical sold in banks of three vessels each of which hold a total of 30,000 scf each or approximately 240 gge. A three vessel bank consists of high, medium and low pressure vessels as well as a computerized priority panel that directs gas from the appropriate bank from to the dispenser hose. Since gas moves in response to unequal pressure, the higher pressure gas in the storage vessels will move to fill the lower pressure vehicle tank. Buffer storage consists of smaller tanks that provide fuel for a very short period (less than a minute) while the compressor ramps up.

Natural gas vehicle tanks are generally filled at 3600 psi, but ambient temperature, as well as the heat of compression and pumping, may cause natural gas to expand, reducing the pressure in the vehicle tank below 3600 psi. As a result the vehicle may not fill completely. In order to rectify this situation, the gas may actually be initially compressed to as much as 5500 psi to compensate for heat-related expansion. An algorithm controls this process known as temperature compensation so that vehicles receive a complete fill.

LNG

Liquefied natural gas (LNG) is methane that is chilled to -270 degrees Fahrenheit. The cold temperatures cause other impurities in the gas to drop out creating a fuel that is approximately 97 percent methane resulting in higher energy density. The higher energy density makes LNG the fuel of choice for long distance transportation.

LNG is stored, transported and dispensed as a liquid. Due to its cryogenic state, LNG easily evaporates and can be gasified to create L/CNG. To date LNG in the U.S. has been produced in large centralized plants and then trucked long distances to fueling stations where it must be stored at very cold temperatures and used within a few days to avoid evaporation. The use of long distance trucking to deliver LNG reduces the emissions benefits of the fuel and could lead to weather-related delivery problems. New developments are making various sizes of on-site liquefaction plants more practical although these products are in the early stages of market introduction. LNG is more difficult to odorize than CNG and must be odorized on site as a safety precaution.

### 3. CNG and LNG: Engines and Applications

Compressed natural gas and liquefied natural gas can be used for a variety of transportation applications.

Table 1 summarizes the typical applications for CNG and LNG and whether they are suitable for CNG, LNG or both.

Table 1: Suitable Applications for CNG and LNG

| Application | CNG | LNG |
|---|---|---|
| Light duty vehicles | X | |
| Transit buses | x | x |
| Refuse trucks | x | x |
| School buses | x | |
| Industrial equipment ie., forklifts | x | |
| Agricultural equipment ie., water pumpers | x | |
| Marine vessels | x | x |
| Shuttle buses and vans | x | |
| Railroad Cars | x | x |
| Long-haul trucks | | X |
| Local delivery vehicles | x | |

Compressed natural gas (CNG) was initially introduced as a transportation fuel during World War II when gasoline was in short supply. Natural gas vehicles (NGVs), however, were not commercially available for an additional four decades. In the 1980s, NGVs were introduced as one of the air quality strategies to reduce criteria pollutants in the air such as oxides of nitrogen ($NO_x$) and particulate matter (PM). The demonstration of NOx and PM emission reductions from natural gas engines led to the adoption of the tiered emission standards that led to the clean engine standards of today. As a result of technological innovations including diesel emission control devices, both diesel engines and natural gas engines now meet the low emission standard set in 2010.

While natural gas engines no longer have a substantial advantage in meeting emission standards, they do often achieve lower emissions in certification testing than their diesel counterparts. The recent adoption of optional NOx standards by California will allow cleaner engines of any fuel type to be certified to a standard below the current requirement, essentially achieving near zero emissions for heavy-duty engines.

From a fleet manager perspective, there are other factors that may influence the selection of natural gas as a fuel. For example, diesel engine technology has become more complex than in the past, requiring the use of selective catalytic reduction (SCR) and other costly add-on technologies. Maintenance and repair of these additional components may increase operating costs. Natural gas engines also have

lower fuel cost (30 to 50% lower than diesel), reduced greenhouse gas emissions and lower maintenance and repair costs. [2]

A major factor in the decision by some fleets to switch to natural gas is the lower cost of fuel. As of April 1, 2014, the national average price for compressed natural gas at the pump was $2.15 compared to $3.97 for diesel.[3] Even though natural gas commodity prices are expected to rise over time, CNG is expected to remain cheaper at the pump than diesel or gasoline for many years to come.

There are three main categories of NGVs currently offered for sale in the U.S. These include:

- Dedicated – NGVs that operate on 100 percent natural gas
- Bi-Fuel – NGVs that are capable of operating on either gasoline or natural gas (the vehicle has two completely separate fuel systems).
- Dual-Fuel – NGVs that operate on natural gas but use diesel fuel for pilot ignition (assistance). This design is primarily used in heavy-duty vehicle applications.

The United States is acknowledged to be one of the last countries to embrace natural gas as a transportation fuel. Worldwide, there are more than 15.2 million natural gas vehicles.. Only a tiny fraction of the natural gas vehicles worldwide are in the U.S. According to NGV America[4], there are over 120,000 NGVs of all types on U.S. roads today. As shown in Table 2, the number of natural gas vehicles declined during the period from 2002 to 2008 but has recently begun growing once more.[5]

Table 2: Historical Trends in CNG and LNG vehicles

| Year | Compressed Natural Gas (CNG) | Liquefied Natural Gas (LNG) |
|---|---|---|
| 1992 | 23,191 | 90 |
| 1997 | 68,571 | 813 |
| 2002 | 120,839 | 2,708 |
| 2007 | 114,391 | 2,781 |
| *2010 | 115,863 | 3,354 |

*last year data available

[2] For example, CNG is transported through existing pipelines in a closed system, without the need to transport the fuel

[3] http://www.afdc.energy.gov/fuels/prices.htmlover-the-road in tanker trucks, as with diesel fuel.

[4] http://www.ngvamerica.org/about_ngv/index.html

[5] EIA's Alternatives to Traditional Transportation Fuels, Table V1. Available at http://www.eia.gov/renewable/

The U.S. market is also different in other ways. In many countries, requirements for conversion kits were minimal. Until recently, however, restrictive U.S. EPA testing requirements, made it difficult to justify the expense of testing multiple engine configurations for a very small market. Recent changes in EPA testing requirements to allow multiple engine/vehicle configurations to qualify under one test protocol have greatly expanded the market for certified CNG engines, creating a new industry of vehicle conversion companies. While these conversions are not all currently legal in California,the California Air Resources Board (CARB) has signaled their intent to conform to EPA's conversion standards and is currently revising their aftermarket conversion regulation.

Today's primary NGV markets are public transit buses (the largest consumer of natural gas as a transportation fuel), and waste collection and transfer vehicles (the fastest growing market segment). Many airports and other government fleets have also adopted natural gas. Private fleets are beginning to adopt natural gas for service vehicles that return to base daily. In some cases, these shifts were driven by local regulations.[6]

Although there are a relatively small number of natural gas engine models, these are typically installed into a variety of vehicle body types by vehicle manufacturers. For example, the same Cummins engine may be used in a refuse truck, a bus or a street sweeper. The following sections examine the availability of various types of natural gas vehicles.

Types of Engines and Vehicles

Although major automakers have been selling dedicated natural gas vehicles in Europe, South America and elsewhere for years, they have not brought these vehicles to the American market, citing lack of demand.[7] In the U.S., only a handful of light duty vehicles have been available, primarily the Honda Civic GX, which has been manufactured in small volumes of around 3,000 per year.

Now, with natural gas having a clear price advantage over diesel, there is renewed interest in vehicles than run on CNG. The federal website Alternative Fuels Data Center has a wealth of information on alternative fuel vehicles including a 2014 Clean Cities Buyers Guide.[8]

[6] For example, the fleet rules of the South Coast Air Quality Management District require government fleets of more than 15 vehicles or private contractors that service government fleets (such as waste haulers) to purchase alternative fuel vehicles.

[7] There were NGVs in the U.S. in the 1990s, but after problems with vehicle tanks, manufacturers withdrew from the U.S. market. Tanks now are much more robust.

[8] http://www.afdc.energy.gov/vehicles/natural_gas_availability.html

Light and Medium Duty Natural Gas Vehicles[9]

In the 2013 and 2014 model years, there are a number of dedicated CNG light- and medium-duty vehicles available for purchase from OEMs:

- Chevrolet Express (2500 & 3500) dedicated CNG Van—OEM vehicle
- GMC Savana (2500 & 3500) dedicated CNG Van—OEM vehicle
- Honda Civic dedicated CNG sedan/wagon—OEM vehicle
- Ford E-250/E-350, F-450/F-550, F-660 (Via Landi Renzo QVM[10])
- Chrysler RAM 2500 hybrid CNG truck—bi-fuel
- Ford Transit Connect--conversion

In October 2013, GM announced that the Chevrolet Impala would be available in a hybrid gasoline and natural gas combination starting in summer 2014, the first new light duty model in some time.

Medium and Heavy Duty Vehicles

There are a number of OEM certified natural gas engine models are being used in a various medium and heavy-duty vehicle models. The engines listed below can be installed by conversion companies or QVMs.

- Cummins Westport ISL G 8.9L (250 – 320 hp)
- Cummins Westport ISX12 G12L (320 – 400 hp)
- Ford Motor Company 2.0L L-4
- Ford Motor Company 5.4L V-8
- Ford Motor Company 6.8L V-10
- General Motors 3.0L
- General Motors 6.0L V-8
- BAF Technologies 6.8

[9]The following information regarding vehicles and engines is primarily drawn from the Alternative Fuel Data Center, NGV America and the American Natural Gas Association http://www.ngvamerica.org/pdfs/Available_Vehicles_and_Engines.pdf

[10] QVM stands for Qualified Vehicle Modifier

The following manufacturers provide certified conversion kits that can be used to add the certified engines listed above to vehicles manufactured by:

- Chrysler
- Ford
- General Motors
- Detroit Diesel
- Cummins
- Caterpillar
- Daimler Chrysler AG
- International Truck and Engine Corp.
- Navistar

There are a large number of companies doing vehicle conversions to CNG.[11] Customers need to check that the companies they are considering use kits certified for the specified vehicle year and model.

Table 3 – CNG Vehicle Conversion Systems

| Company | Website |
|---|---|
| Altech-Eco Corporation | www.altecheco.com |
| American Power Group | www.americanpowergroupinc.com |
| AutoGas America | www.autogasamerica.com |
| BAF Technologies | www.baftechnologies.com |
| Clean Air Power | www.cleanairpower.com |
| EcoDual | www.ecoduel.com |
| Go Natural CNG | www.gonaturalcng.com |
| Greenkraft | www.greenkraftinc.com |
| High Pressure Group | www.highpressuregroup.com |
| IMPCO Automotive | www.impco.ws |
| Landi Renzo USA | www.landiusa.com |
| NatGasCar | www.natgascar.com |
| NGV Motori | www.ngvus.com |
| Peake Fuel Solutions | www.peakefuelsolutions.com |
| Westport LD | www.westport.com |
| Wise Gas | www.wisegasinc.com |

Information regarding vehicles, engines and certified conversion kits changes rapidly. Customers considering conversions should check one of the available sources of information about the latest

[11] Please note this information changes rapidly. Please contact the manufacturer, NGVAmerica or the federal clean vehicles website www.afdc.energy.gov for the latest information.

certified systems and conversion companies. Updated information is available at http://epa.gov/otaq/consumer/fuels/altfuels/altfuels.htm#4.

This source also lists the certification status of each conversion system, which is important to ensure that local emission requirements are met. Another source of information is the Clean Cities Guide to Alternative Fuel and Advanced Medium-and Heavy Vehicles. (http://www.afdc.energy.gov/uploads/publication/60448.pdf)

### 4. Determining Fueling Infrastructure Needs

In discussions about alternative fuel transportation in the U.S., there is almost always a reference to the "chicken and egg" phenomenon—that is, does infrastructure development drive vehicle sales or do vehicle sales drive infrastructure development. There is no clear winner in this debate, but clearly infrastructure development is crucial to the continued success of natural gas-powered vehicles.

The vast majority of CNG and LNG fueling occurs at public stations similar to gas stations or at centralized fleet fueling sites. Infrastructure costs range from $100,000 for lower capacity equipment and installation, to over $1.5 million for larger CNG stations or $4 million plus for LNG fueling.

As shown in Table 4, there are a total of 1,535 CNG fueling stations in the U.S. and 172 LNG fueling stations. Only half the CNG stations and LNG stations are open to the public--the balance are for fleet or private use only. By contrast there are over 125,000 gasoline stations in the U.S. and over 8,000 EV charging stations.

It can be argued that not as many public CNG and LNG stations are required compared to gasoline or diesel, because most vehicles return to base each day for fueling; however infrastructure development is clearly still an issue for the alternative fuel industry.

Table 4: Public and Private Access PEV, CNG and LNG Fueling Stations[12]

| CNG and LNG Stations | CNG | LNG |
|---|---|---|
| Total* | 1535 | 172 |
| Public Access | 711 | 52 |
| Private Access | 824 | 120 |

A fleet manager considering purchasing CNG light, medium or heavy duty vehicles should ask the following questions to determine what type of infrastructure is needed and/or available.

[12] http://www.afdc.energy.gov/locator/stations/

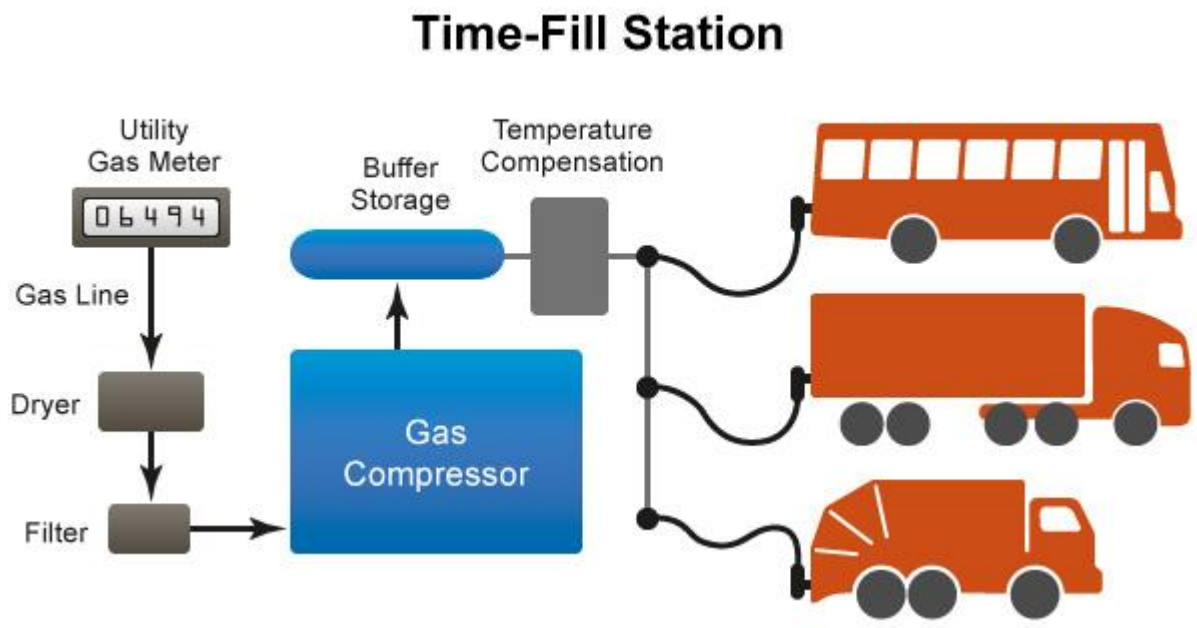
- What are the daily distances travelled?
- Duty cycle—one way or round trip—does the vehicle return to base overnight?
- Are there existing public access fueling stations?
- Time available for refueling—can the vehicles be filled overnight or do they need to be fast-filled (similar to a gas station)?
- Public vs. private access—will there be public access to the station?
- What are the economics of building a station vs. using public infrastructure (if available)?

CNG 101

CNG fueling operates on the principle of equalizing pressure. If a vehicle comes with its tank at 600 psi and the storage is at 4000 psi, the gas will flow into the vehicle tank until the pressure in the two tanks is equal. As a result, the amount of fuel that can be dispensed from storage will depend on the difference between the pressure of the dispensing storage tank and the receiving vehicle tank.

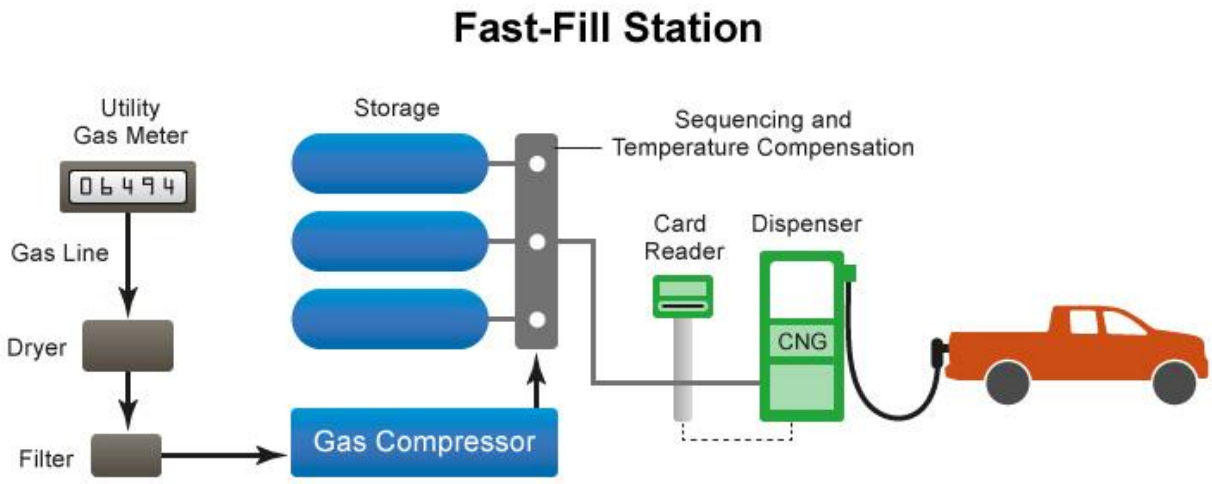
*Time Fill and Fast Fill*

CNG fueling is generally one of two types: time-fill or fast-fill. Time-fill is a slow fueling process (typically overnight) that allows fleets of large vehicles to fill simultaneously over a 6 to 12 hour period. Time-fill works well for transit buses, school buses, service vehicles and other fleets where vehicles are parked overnight. Figure 1 provides a schematic of how time-fill works.

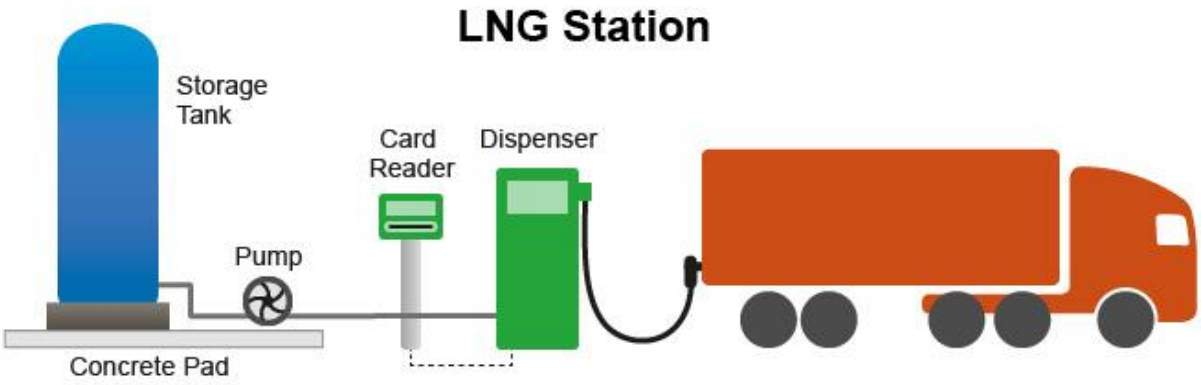



Fast-fill is similar to a gas station model with a large compressor and dispenser. Unlike gas stations which keep thousands of gallons in underground storage, CNG stations often have three-packs of above ground storage vessels where 240 to 300 gallons of compressed gas are stored. Vehicles are filled either from the storage vessels or directly from the compressor, depending on the compressor equipment

manufacturer. Typically, the compressor will refill the storage during off-peak periods while there are no vehicles fueling[13]. Figure 2 illustrates a typical fast fill CNG station.[14]




LNG is similar to CNG with the difference that the gas is chilled to -270 degrees centigrade so that it becomes a liquid. Figure xx illustrates the components of an LNG station. [15]




**5. Components and Manufacturers**

CNG fueling stations come in many shapes and sizes. The right CNG station for a given customer will depend on several factors:

[13] http://www.afdc.energy.gov/fuels/natural_gas_cng_stations.html
[14] http://www.afdc.energy.gov/
[15] http://www.afdc.energy.gov/

1. Inlet pressure—the pounds per square inch (psi) available at the utility meter
2. Flow—the amount of compressed natural gas that can be dispensed in a minute (standard cubic feet per minute or scfm). The flow can also be communicated as gasoline gallon equivalent (gge) units per minute. Approximately 125 scfm equals one gasoline gallon equivalent and 135 scfm equals one diesel gallon equivalent but the number varies depending on the definition of standard conditions. In addition, because gas composition varies slightly from location to location, the amount of energy (btu) in each gasoline gallon equivalent of natural gas will also vary. Using btus as the unit of measure eliminates this problem.
3. Duty cycle—the specifics of the individual application will determine what kind of CNG compressor is needed. Smaller compressors produce anywhere from a fraction of a gge per hour to about 2 gge per minute. On the other end of the spectrum, high horsepower compressors can produce as much as 12 to 15 gasoline gallons per minute or more.

*Station Components*


CNG stations typically consist of a number of components that may be separately mounted on a skid or incorporated into a single cabinet. Components from multiple manufacturers may be combined into fueling systems by integrators or packagers. Some or all of the following components are typically found in a CNG fueling system (with examples of manufacturers in parentheses).

- Compressor (IMW i, Ariel, Bauer, Ingersol Rand)
- Dispenser with point of sale or fuel management system (Greenfield, Gilbarco, Wayne-Dresser)
- Time-fill posts for overnight fueling
- Fast fill post without point of sale or fuel management (for private fleet applications)


- Dryer (removes moisture from gas—can automatically dry desiccant or require manual replacement (Xebec)
- Storage (ASME (American Society of Mechanical Engineers certified vessels by various manufacturers)
- Priority panel (controls the storage vs. compressor sequencing)
- Program logic controller (controls the compressor parameters)
- De-fueling post to remove fuel for doing maintenance or repair work on a vehicle

Appendix A provides a list of the companies involved with CNG infrastructure and their roles as component manufacturers or fueling solution providers. Please note that this information changes rapidly and it is best to look up the most recent information on the internet.

LNG stations have additional components that remove impurities and chill the natural gas to a liquid state.

*Certification by a National Recognized Test Laboratory*

In permitting and approving any type of electrical or mechanical equipment, Local Building Officials typically look for the systems to be listed by a Nationally Recognized Test Laboratory (NRTL). Although the most widely recognized NRTL is Underwriters' Laboratory (UL), there are at least a dozen NRTLs that may be accepted by local jurisdictions.[16] Compressed natural gas stations are typically not UL listed as a unit, even though individually electrical components are listed. There are several reasons for this:

- CNG stations are individually designed and built to fit a specific customer application and specific site condition--no two stations are exactly alike
- U.S. test labs such as UL are not equipped to certify natural gas equipment although they may be approved by other NRTLs such as the AGA (American Gas Association) and CSA (Canadian Standards Association).

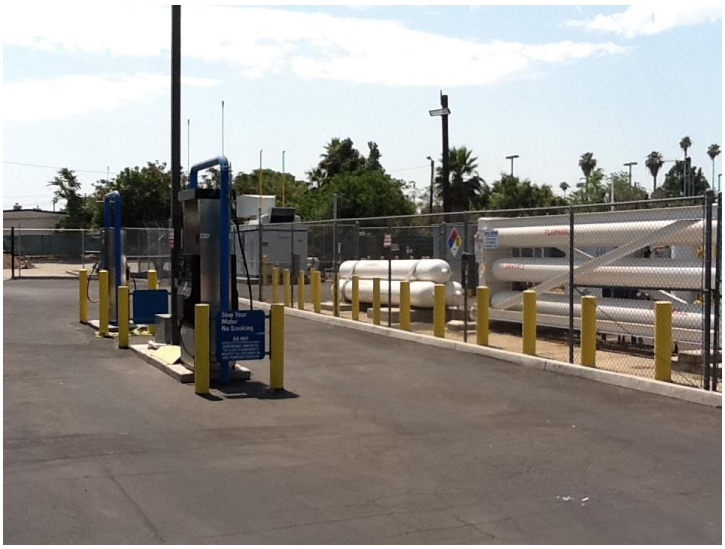
Some local jurisdictions require field certification of installed systems. In this case an approved test lab comes out to the site to confirm that all components and their assembly meet the applicant listing standards. Other agencies accept written reports of testing and listing of components by independent laboratories. Cities typically have a list of independent test laboratories such as UL that are accepted. The City of Los Angeles has its own test laboratory.

[16] https://www.osha.gov/dts/otpca/nrtl/nrtllist.html

**6. Station Design and Specifications**

There are many options for the prospective station owner to consider in designing a station. To start, the fleet owner or site owner must take a number of factors into account.

1. The most critical factor is the location of the gas utility's distribution line and the inlet pressure at the site. If gas is not available on the site or the pressure is too low, additional distribution capacity might need to be added by the utility. Most compressors need approximately 14.5 psi of pressure (1 bar) to operate but in some parts of the U.S. 2 to 5 psi of pressure is typical.
2. The second key consideration for designing a CNG station is the throughput or demand. Are the vehicles being time-filled or fast-filled? How many vehicles must be filled over what period of time? How many gallons does each vehicle need? What is the duty cycle of the station over a 24 hour period—are there morning and evening peaks or is usage heavy at other times? What are the plans for growth? The answers to these questions will determine the total gallons and gallons per minute needed and the size of the compressor needed to achieve that flow. See Appendix C for sample calculator sheets for deterimin total gallons and flow.
3. Other factors are dictated by the codes governing the design and construction of CNG and LNG fueling stations. These codes are discussed below.



Beyond these primary factors, there are other things to take into considerations such as the location, capital cost for equipment and installation, any available grant funds, maintenance, fuel cost and long term operating costs. Potential station owners should become familiar with the industry terminology and available equipment options. There are many resources available to help in the process:

- The local natural gas utility can inform customers about local gas pressures, fuel costs and the location of the nearest pipeline. Many utilities even have programs to encourage customers to use compressed natural gas for transportation. Utilities may also provide a list of potential vendors for engineering and components.

- The Drive Natural Gas Initiative of America's Natural Gas Alliance provides some excellent information about the benefits of natural gas.
- The American Gas Association has a CNG infrastructure guide that includes sample designs, footprints and typical costs.The federal Alternative Fuel Data Center at the Department of Energy (www.afdc.energy.gov) provides access to a wealth of information including case studies, cost calculators and "how to" guides.
- The websites for industry sources such as America's Natural Gas Alliance (http://anga.us) or the Natural Gas Vehicle Coalition (http://www.ngvc.org/) are also very helpful.
- Conferences such as the annual NGVA conference, and seminars such as "The Compelling Case for Compressed Natural Gas" (NGVA) and CNG Fueling Station Design (conducted by the Natural Gas Vehicle Institute) provide opportunities to meet vendors and consultants as well as hear from those who have gone through the process of installing CNG or LNG infrastructure.
- There are a number of consultants who have been designing and building CNG stations from many years and can be helpful in recommending options and developing bid specifications.

Designing for Redundancy

About 20 years ago, in the early days of CNG infrastructure construction, the reliability of the CNG fueling equipment did not always match customer's expectations. Sometimes, customers did not understand that CNG systems need regular checkups and maintenance. Customers who had invested hundreds of thousands of dollars in new natural gas trucks and fueling infrastructure were very sensitive to service interruptions. As a result of the spotty performance track record, many consultants and engineers started recommending redundant compressors to ensure better reliability. Although equipment reliability has improved a great deal, customers need to decide whether the need for guaranteed performance outweighs the additional expense of redundant compressors.

## 7. Codes and Local Building/Zoning Regulations

Given the flammable nature of CNG and LNG, safety is of paramount concern. Stations need to meet all applicable federal, state and local codes and requirements. Station owners should use an engineering firm with experience in designing compressed natural gas stations. It is also a good idea to meet with the City Planning Department at an early stage to introduce the project, confirm that the station is situated on an appropriately zoned parcel and determine any specific local requirements that must be met All codes are subject to interpretation by local authorities having jurisdiction who make the ultimate decision on compliance.

The primary code governing compressed natural gas and liquefied natural gas stations is NFPA 52 which is described as follows:

*Provisions cover the design, installation, operation, and maintenance of CNG and LNG fuel systems on all vehicle types--plus their respective compression, storage, and dispensing systems. This Code applies to all facilities with LNG storage in containers of 70,000 gallons or less.* [17]

The current version of the code developed by the National Fire Protection Association is 2013. Most jurisdictions have adopted this code although some may be using older versions. Appendix B lists the relevant chapters of the NFPA for permitting CNG stations. INSERT TABLE FROM ANGA CNG GUIDE

Other Important Codes include:

NFPA 70—National Electrical Code

NFPA 55--Compressed Gases and Cryogenic Fluids Code (sections related to CNG are included in NFPA 52)

FMVSS (DOT) 304 Compressed Natural Gas Container Integrity

Uniform Building Code (UBC)

Uniform Plumbing Code (UPC)

ASME B31.3 (Plumbing)

ASME (section 8)

- Section 523. Design and Construction of CNG Tanks
- Section 524 Design and Construction of Compressed Natural Gas Cylinders
- Section 530 Approval of Devices
- Section 531 Location of Storage tanks and Regulating Equipment
- Section 532 Installation of Above Ground Storage Tanks
- Section 536 Piping Standards
- Section 541 Safety Relief Valves

There are also some California-specific codes that need to be following including:

- Uniform Building Code (UBC)-- Seismic Zone 4—for footings, founding and soil for dryer, compressor and storage vessels
- UBC must meet wind requirements up to 70 miles per hour for dryer, compressor and storage vessels
- CAL-OSHA Title 8 Article 7 Unfired Pressure Vessel Code for safety for pressure Vessels (CNG storage containers)

[17] http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=52

Zoning

Local building codes and regulations are also of critical importance. Land use is governed by local zoning laws and as a result CNG stations can only be constructed where permitted by local zoning. Since CNG and LNG are relatively new fuels, they may not be specifically called out in zoning regulations. Typically CNG and LNG stations are permitted wherever gasoline fueling stations are allowed including industrial and commercial zones. However, based on NFPA 52, CNG stations will have some specific requirements due to the nature of the fuel including:

- Setback of 15 feet from a residential property line
- Class I Division I rating for all components within a 5 foot radius of the compressor or dispenser

In some cases, even residential fueling may be permitted. For example, the City of Chino has taken the forward-looking step of requiring new home construction to include plumbing for a possible home natural gas fueling appliance.[18]

If a fueling station is not a permitted use at the desired location, the site owner can appeal to the local Planning Commission for a variance however this will add time and cost to the approval process.

In addition to zoning regulations, local governments may have their own municipal codes that impact construction of a CNG station, including:

- City Fire Codes
- Local Building Ordinances
- Local Noise/Lighting/Traffic ordinances
- Any local requirements that are more restrictive than the national codes

Prospective station owners should familiarize themselves with local design and construction requirements to avoid costly delays.

[18] http://www.cityofchino.org/home/showdocument?id=129

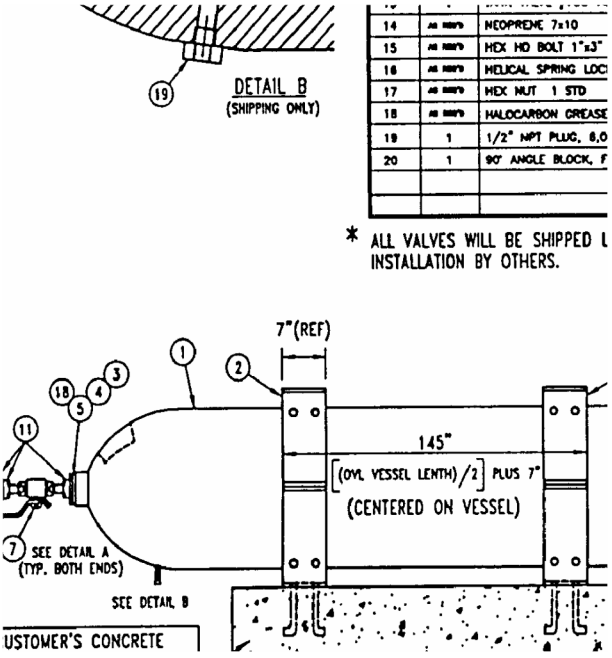
## 8. Permitting and Construction Process

The following steps are suggested to help ensure efficient and timely permitting process for a CNG station. The most important advice is to start the permitting process early—at least 9 months before the anticipated construction date. Prior to beginning the permitting and construction process, owners may wish complete Step 1 below to ensure that the project is feasible and also select equipment and installation vendors. Most owners follow some sort of bidding process to assess the available options and range of prices. Once selected the equipment vendor and installation contractor can help navigate the permitting and installation and start up procedures.

STEP 1: Set up an initial meeting between the end user applicant and the Planning or Community Development Department. The agenda should include discussion of the following items:

- Zoning classification of proposed station to determine if it is a permitted use
- Any approvals required to allow the station as a permitted use ie., is a general plan amendment required? Is a variance required or a conditional use permit?
- Based on the zoning regulations, what setbacks are required from the property line?
- Are any special clearances required for explosion proofing
- What environmental review, if any, is required under the California Environmental Quality Act (CEQA)
- Are there any noise or odor issues based on the neighboring properties
    - CNG station noise standard is 85 dBa (OSHA limit without hearing protection); can be reduced to 70 dBa at property line with enclosure or noise reduction package
- Review of scope of CNG station project—is it public or private?
- Are there any additional traffic or circulation issues created by the station
- Approval process and timelines—typically approvals for construction permits will be required from:
    - Planning
    - Building and Safety
    - Public Works
    - Fire Department
    - Traffic
- Some cities may have additional reviews such as landscaping, architectural, or design review
- Number of sets of plans and calculations to be submitted
- What fees are due by when

- The local jurisdiction may also wish to confirm that the end-user has contacted the local gas utility to obtain inlet pressure and any other utility requirements for natural gas delivery to the site
- Also if local jurisdiction is not familiar with compressed natural gas fueling, they may wish to do some research on line, contact their peers in neighboring cities with CNG stations to see how they handled permitting, visit similar sites or meet with the local gas utility representative for an orientation. A list of resources for additional information is at the end of this guide.
- Once it is determined that the project is feasible and there are no major obstacles such as zoning restrictions, the prospective station owner can proceed to Step 2.




STEP 2: Prepare and submit permitting package to the City; place equipment order

In addition to any specific local requirements, the package should include:

- Civil Drawings and Specifications stamped by a Registered Engineer:
  - A plot plan showing the surrounding area and streets as well as the placement of the station on the property
  - Foundations and Structures
- Mechanical Drawings and Specifications stamped by a Registered Engineer:
  - Piping and Instrumentation Diagram (P&ID) including piping, tubing, vessels and mechanical equipment
- Electrical Drawings and Specifications stamped by a Registered Engineer:
  - Single Line electrical diagram
  - Electrical distribution system, panel schedules, grounding and load calculations
  - Safety sign package

- Grading Plan
- Preliminary schedule
- Submittal of the permit package will be followed by a series of reviews by various city departments (Fire, Building and Planning or Community Development) with possible comments and corrections at each step until a set of plans is approved by the city.

Step 3 Permit Received, Equipment Received, Construction

- Determine milestones for inspections

Step 4 Commissioning begins

- Final electrical hookups

- Any Utility work completed
- Utility metering installed

Step 5 Final inspection by local jurisdiction and signoff

**9. First Responder and Technician Training**

As a result of the properties of natural gas, the response of emergency personnel to a natural gas fire must be different from the response to a petroleum fuel fire or an electrical fire. With more alternative fuel vehicles on the road than ever before, there is a growing need to provide systematic training for police and fire personnel (also called first responders). A recent survey by the Center for Sustainable Energy found that half the fire chiefs who responded reported a lack of alternative fuel emergency incident training. Budget limitations and scheduling issues also constrain fire and police departments from offering such training.


The study also pinpointed a need for trained technicians who can service alternative fuel vehicles. The Fleet Managers interviewed indicated that with adoption of alternative fuel vehicles expected to grow rapidly, the demand for training will only increase.

Several training options for first responders already existing through the National Alternative Fuels Training Consortium (NAFTC). The Consortium offers a curriculum for First Responder Safety Training program to consortium members.[19] A four hour workshops or a more extensive two day training are offered around the country by affiliates of NAFTC. The four hour program is also offered as part of the Clean Cities Learning Program.

Locally the Advanced Transportation and Renewable Energy program of California community colleges has developed a natural gas vehicle technician program that is available at many community colleges. Technician training is also available from the Natural Gas Vehicle Institute through its courses around the country.

**10. Installation Cost**

Installation costs for CNG stations vary greatly, based on site conditions, local design requirements, national codes and equipment design. Depending on the design of the system and the components, construction will include a concrete pad for each component (dispenser, compressor, dryer, storage), trenching to connect each component to the others and an electrical hookup to a 200 to 400 amp panel

[19] http://afvsafetytraining.com/

to run the compressor. Installation costs can range from $10,000 to $1.5 million although most are in the $200,000 to $500,000 range. LNG station installation costs can range from $1 million to 4 million.[20]

### 11. Commissioning, Warranty and Service

Once a CNG or LNG station is installed, the compressor manufacturer or integrator will go through a commissioning process to test all components and ensure everything is working properly. After the equipment has been turned over to the customer, it should be covered by the manufacturer's warranty for 12 to 18 months. Warranties may include parts only or parts and labor. Extended warranties are usually available from the manufacturer or integrator.

Compressors consist of motors and mechanical components that need regular maintenance. Routine checks and regular maintenance are key to ensuring a long life for this major capital investment. In the 1980s and 1990s when the first compressed natural gas fueling infrastructure was being developed, the importance of maintenance was not always communicated to early adopters, resulting in many frustrated owners and drivers. Today manufacturers and third parties offer operation and maintenance programs. There are also training programs available for service technicians. Owners can choose to train their own technicians or contract with third parties for maintenance and service. With regular maintenance and compressor overhauls as needed, a CNG or LNG station should last 20 years or more.

### 12. Operating Costs

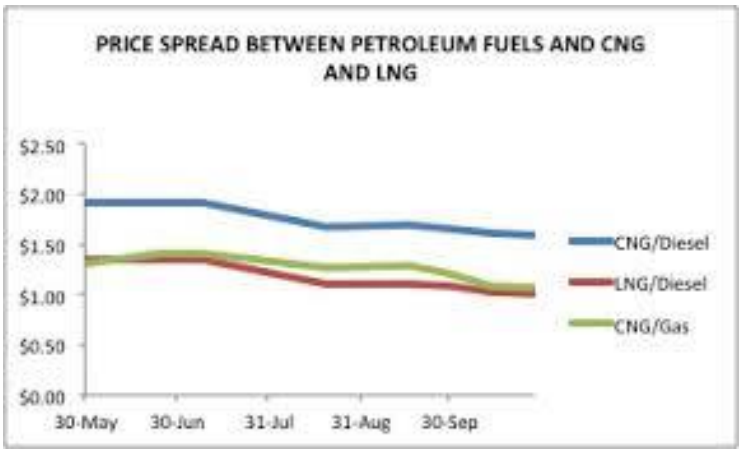
Operating costs for CNG and LNG fueling stations include of the following components at a minimum:

- Cost of Fuel—commodity cost plus transportation and taxes
- Cost of Electricity
- Maintenance including oil, filters, replacement parts
- Unscheduled service
- Equipment overhauls at manufacturer set intervals (based on hours of operation)

[20] http://www.afdc.energy.gov/fuels/natural_gas_infrastructure.html#cost plus installation experience of Clean Fuel Connection, Inc.

Fuel

In recent years, natural gas has become an abundant fuel in the U.S. as a result of technological advancements in extraction technology (hydraulic fracturing or "fracking"). A few years ago, commodity prices for natural gas sank to record lows. Prices have since increased some from that historical low, but according to the 2040 forecast of the U.S. Energy Information Agency, natural gas prices are expect to remain relatively low compared to gasoline and diesel.[21] Table xx illustrates the trend for a recent period.[22]




Electricity

An additional operating cost is the electricity to operate the compressor. The cost of electricity on a monthly or gallon equivalent basis will depend on the number of hours the compressor operates to fill storage or provide direct fills. The bill will be determined by the utility's commercial rate, demand charges, time of day or seasonal rates. How many hours the compressor operates is determined by the demand for fuel, the size of the compressor and the capacity of storage vessels.

Some real world examples are provided below.

Example 1:

A public refueling station in an investor owned utility region of California dispenses approximately 280,000 gge per year. The station has a 125 hp compressor and provides both fast filling and time fill. The electricity usage for the station was 165000 kWh per year (or 654 kWh per weekday) at a total cost of $31,618 for a cost per kWh of $.19. Looking at it on a per gallon basis, each gallon of CNG costs $.11 of electricity to produce.[23] If we assume a $.12 per kWh rate, the demand charges account for $.07 per kWh.

[21] Energy Information Agency, Annual Energy Outlook 2013

[22] NGV Today, August 6, 2014

[23] A total of 24,863,500 scfm is produced annually at a cost of electricity of $31,618. At a conversion rate of 125 scfm=1 gasoline gallon, the cost of electricity to produce one gallon is $.11.

[23] Email from Sempra Utilities 8/16/13.

Example 2:


A smaller station in a municipal utility area of California dispenses 58,600 gge annually. The 75 hp compressor uses 79,680 kWh per year and total electricity costs are $17,173 or $.22 per kWh. Each gallon of CNG costs $.29 of electricity to produce. If we assume a rate of $.12 per kWh, a total of $.17 per kWh goes to demand chargers on this less efficient system.

The conclusion that can be drawn from these examples is that larger stations with more throughput are less costly on a per gallon basis. The greater the volume, the lower the cost per gge since the electricity demand costs are spread over more throughput. [24]

Maintenance and Service

Reliable operation of a CNG station requires daily, weekly and monthly checks and service. A daily visual and auditory check for leaks or unusual noises or vibrations can detect small problems before they become major mechanical problems or safety hazards. A few of the recommended steps for long and reliable operation include:

- Daily, weekly and monthly visual checks for leaks, vibrations or unusual noises
- Purging excess oil and adding oil when necessary (usually weekly---either mineral oil or synthetic oil can be used)
- Replacement of oil and filters
- Maintenance at 2,000 hour intervals
- Major overhauls or rebuilds at specified intervals (typically 6-8,000 hours of operation)

Table 5 provides a broader look at typical operating cost ranges for CNG station operation and an estimate of cost on a per GGE or DGE basis. This information was developed by Steve Yborra at the Clean Vehicle Education Foundation as part of the Compelling Case for Natural Gas workshop.[25]

Table 5 Components of CNG Cost

| | **low** | | **high** | |
|---|---|---|---|---|
| Natural gas (gallon) | $ | 0.64 | $ | 0.91 |
| Gas Commodity | $ | 0.52 | | |

[25] PowerPoint presentation Jared Hightower, Greenfield, not dated

| | | |
|---|---|---|
| Transportation to local distribution companies (LDCs) via interstate pipelines to LDC's "city gate" | $ 0.04 | $ 0.04 |
| Local gas company service fee to transport gas to customer meter | | |
| State/local gross receipts/use taxes and/or special assessments | | |
| Electricity for compression | $ 0.09 | $ 0.30 |
| Maintenance/repair | $ 0.15 | $ 0.30 |
| Capital Amortization | $ 0.35 | $ 0.50 |
| Federal motor fuels excise tax | $ 0.18 | $ 0.18 |
| State motor fuel excise tax | $ 0.08 | $ 0.30 |
| Taxable fuel sales | $ - | $ 0.10 |
| Total | $ 2.05 | $ 2.63 |
| Notes: assumes no grants or other buydowns of equipment cost, no profit margin, | | |

Facility Upgrades

Fleets that service their own vehicles need to make modifications to maintenance facilities to allow servicing of vehicles that operate on CNG or LNG. Local and national building codes have strict requirements, including pressure gauges, leak-detection equipment, ventilation, etc.

**13. Ownership Models and Return on Investment**

There are a number of ownership models for CNG and LNG fueling stations including:

- Outright purchase (cash or bank financed)
- Financing through local distribution utility (capital investment by utility, paid back over time through the monthly utility bill)
- Capital equipment lease (usually equipment only-- financing with buyout at the end)
- Third party ownership—party owns and operates station for a fixed monthly price or a price per gge
- Compression services rental (third party owns and services the equipment but customer operates the station)

In all cases, the end user can choose to operate the station or contract with a third party to operate and service the compression equipment.

The right choice for each fleet or station developer will depend on a number of factors, including budget, available incentives and expected throughput or volume of CNG dispensed. As shown earlier, the initial capital outlay for a CNG or LNG station is substantial, potentially millions of dollars. In addition to the economics of the fueling station, any return on investment calculation must also factor in the significant cost of purchasing new vehicles or converting existing vehicles to natural gas. Regional, state and federal tax credits and incentives may be available to help offset the initial capital cost. The good

news is that with the current 50 to 90 percent price differential between diesel and natural gas, the more CNG or LNG used, the more fuel savings generated for the end user and the faster the return on investment. C

Calculating Return on Investment.

While every company, government agency, consumer or fleet should conduct their own cost-benefit analysis based on local conditions, there are now some excellent tools in place to assist potential users in evaluating the best AFV options. Many of them focus on the costs/benefits of alternative fuel vehicles including infrastructure, but not infrastructure as a separate analysis.

The *Clean Cities Vehicle and Infrastructure Cash-Flow Evaluation (VICE) Model* is a thorough Excel-based framework that helps fleet managers assess CNG as a viable alternative to diesel for their operations. While it focuses on public fleets such as buses and refuse trucks, it can be used for private fleets as well. The model provides default inputs but recommends fleets use their own data if available. VICE helps fleet managers estimate the return on investment and payback period for up-front costs that include infrastructure and incremental vehicle cost. The website, provides a thorough description of the VICE Model, required data inputs, and the model's default assumptions. http://www1.eere.energy.gov/cleancities/news_detail.html?news_id=17674

*FuelsNews* has two easy-to-use widgets that allow you to the calculate fuel savings based on current diesel and CNG prices. A second widget allows fleets considering CNG to calculate the return on investment.[26]

The *ECOCat Vehicle Selection Calculator* from the University of New Hampshire is another excel-based tool that includes vehicle price, miles per gallon (MPG), and greenhouse gas emissions to represent the full life cycle and environmental costs of selecting vehicle ownership. Unfortunately the calculator is not interactive and maintenance is not included but it is useful for viewing the differential cost of various light-and medium-duty vehicles. http://www.unh.edu/facilities/ecocat_calc.html

Some additional resources describe the tradeoffs of converting to CNG or LNG or the emissions benefits. A few examples are:

- The AFDC Vehicle Cost Calculator offers the ability to compare capital and operating costs of gasoline and alternative fuel vehicles.[27]
- Environmental Defense Fund: http://business.edf.org/projects/fleet-vehicles/fleet-calculator
- Article on the Factors to consider in converting to CNGhttp://www.government-fleet.com/channel/green-fleet/article/story/2013/04/exploring-the-total-cost-of-cng/page/2.aspx

[26] http://www.fuelsnews.com/cng-vs-diesel/;http://www.fuelsnews.com/cng-roi-widget/#
[27] http://www.afdc.energy.gov/calc/

- Ford Motor Company's sales staff will work with fleet customers to evaluate vehicle purchase options using their "Fleet Vehicle Emissions and Fuel Cost Calculator". http://www.government-fleet.com/channel/green-fleet/article/story/2012/10/ford-debuts-fleet-vehicle-emissions-fuel-cost-calculator.aspx?prestitial=1
- EPA provides a number of calculator tools and vehicle guides that support the emissions and greenhouse gas reduction benefits of a switch to electric or CNG vehicles: http://www.epa.gov/otaq/stateresources/tools.htm

Finally, an information paper prepared for the Columbia Williamette Clean Cities Coalition in Oregon provides some simple, easy-to-understand payback models for CNG trucks of various sizes. Payback is based on the difference in fuel cost between diesel and natural gas and ranges from a low of 3.7 years to a high of 17 years, based on annual miles driven.[28] The paper also estimates that monthly sales of 25,000 GGE of natural gas is required to provide an investment grade rate of return on a capital cost of $675,000 to $1 million for a fueling station.

**Case Studies**

The AFDC[29] and Clean Cities websites[30] offer many case studies of conversions to electricity or CNG. Most do not provide great detail on costs and savings but are useful for obstacles encountered and overcome. An example is cited below:


[28] Oregon Natural Gas Transportation Fuel: Information paper, March 2013 unpublished
[29] http://www.afdc.energy.gov/case/
[30] http://www1.eere.energy.gov/cleancities/

*Smith Dairy in Ohio* *Smith Dairy Trucking's has over 400 vehicles—primarily Class 8 refrigerated trucks and trailers, which are responsible for local and national product distribution for Smith Dairy in Orrville, Ohio; Wayne Dairy in Richmond, Indiana; and Pacific Valley Dairy in Pacific, Missouri. In 2012 Smith took the first step toward reducing its dependence on diesel fuel by opening a publicly-accessible natural gas fueling station and deploying six CNG tractors out of its Orrville Distribution Center. The initial investment was made without any type of grant funding. One year later, Smith Dairy Trucking has exceeded its original estimates for emissions reductions and petroleum savings. The public fueling station has also been a success and is now selling over 13,000 gge of natural gas per month. Smith expects the station to pay for itself in 5 years.*

American's Natural Gas Alliance has also published a group of case studies for government fleets called "Natural Gas Works for Cities." The thirty examples of municipal fleets that successfully converted to CNG include:

- The City of Los Angeles' Metro bus system which is 99 percent CNG
- San Francisco's CNG taxi fleet which is 92 percent CNG
- Tampa Bay Florida's fleet which will ultimately number 70 CNG refuse trucks.

**14. Grants, Incentives and Tax Credits**

Federal, state, and local agencies have actively promoted the alternative fuel vehicle market through a variety of grants, incentives and tax credits for the business and consumer market. The types of programs that have been funded include:

- Tax credits for vehicles or infrastructure
- Manufacturing incentives and credits
- Research and demonstration programs
- Guaranteed loans
- Grants for vehicle or infrastructure incentives
- Educational programs
- Advocacy programs
- Fuel credit (for CNG)
- Single occupant alternative fuel vehicles
- Building code requirements for new construction
- Technology forcing regulations
- Clean Cities grant programs

It is difficult to present a comprehensive picture of grants and tax credits opportunities since the availability changes rapidly. The best way to stay informed about funding opportunities is to check several of the more comprehensive websites frequently and subscribe to notifications from regional and state air quality agencies. Among the best sources of information are the following websites:

http://www.afdc.energy.gov/laws/local
http://www.driveclean.ca.gov/Calculate_Savings/Incentives.phpRegional Incentives

The websites for industry sources such as America's Natural Gas Alliance (http://anga.us) or the Natural Gas Vehicle Coalition (http://www.ngvc.org/) are also very helpful.

In California regional air districts have offered a number of incentive programs for CNG and LNG vehicles and infrastructure. Some of these opportunities are through state-wide programs such as Carl Moyer Memorial Air Quality Standards Attainment Program and others are locally funded by annual motor vehicle registration fees. Check with local air districts such as South Coast Air Quality Management District, Bay Area Air Quality Management District and San Joaquin Valley Air Pollution District for current programs.

Some cities also have local incentives for encourage the purchase of alternative fuel vehicles or infrastructure. For example, the City of Riverside, CA offers residents a $1,500 incentive for a qualified CNG vehicle or Hybrid electric vehicle purchased from a Riverside dealership. The City of Chino requires new homes to include plumbing for natural gas fueling. Other communities follow the California Green Building Code or LEED standards which include environmentally benign building practices.

A number of federal departments also offer specific vehicle or infrastructure funding programs. Some of the most popular ones are listed below. Check the AFDC website or with individual federal departments for updates on available opportunities and deadlines:

*Bus and Bus Facilities Program:* This program provides capital assistance to purchase new and replacement buses. State and local governments, public agencies, private companies engaged in public transportation, and private non-profit organizations are eligible to apply for funds.


*Clean Fuels Grant Program*: This competitive grant program provides funds to acquire clean fuel vehicles and related equipment, build infrastructure and facilities, and renovate existing facilities to accommodate clean fuel vehicles. At least 65% of funds must include bus-related projects, and 10% must focus on facilities and infrastructure. The program is expected to provide $8.5M in funding in 2013.[31] The Niagara

[31] U.S. Senate Banking. "Federal Transportation Act of 2012." http://www.banking.senate.gov/public/_files/Transit_Bill_Summary_and_Funding_Chart.pdf. Page 2. Accessed May 2, 2013.

Frontier Transportation Authority in NY received $2 million to build a CNG fueling station under this program in 2012. The Kansas City Area Transportation Authority received $1.4 million to replace aging diesel buses with new CNG vehicles.[32]

*Congestion Mitigation and Air Quality (CMAQ) Improvement Program*: This funding program supports state departments of transportation, municipal planning organizations, and transit agencies. Projects related to PEVs and NGVs include developing alternative fuel infrastructure and converting public fleet vehicles to operate on cleaner fuel.[33] Funding amounts and guidelines vary based on the specific funding opportunity. Funds are generally available in areas of maintenance or non-attainment for federal ozone, carbon monoxide and/or particulate matter standards. Recipients are usually state departments of transportation, metropolitan planning organizations, or other approved entities. CMAQ is currently part of the federal MAP-21 program, which provides just over $2.2 billion in CMAQ funding for 2013 and 2014. Alternative fuel projects funded under this program have included public transit bus CNG infrastructure funding in Atlanta and Philadelphia, and a public CNG fueling station in Chicago.[34]

*TIGER Discretionary grants*: The National Infrastructure Investments Program offered $474 million in FY2013. This program began as part of the Recovery Act of 2009, and focuses on capital investments in surface transportation infrastructure. Eligible applicants include state, local and tribal governments, transit agencies, port authorities, metropolitan planning organizations, other state or local agencies, and multi-state or multi-jurisdictional groups applying together. Public transit projects are one type of eligible project. A key project criterion is environmental sustainability, meaning improvement in energy efficiency, reduction in dependence on oil, reduction in greenhouse gas emissions, and benefit to the environment.[35] The program awarded $500 million in 2012. Muskegon County, MI was awarded $1.35 million to purchase three CNG buses. Applicants for these funds compete with rail, road and port projects, which made up most of the funded projects.[36]

*Office of Energy Efficiency and Renewable Energy grants:* The agency offers various funding opportunities for business, industry and universities; some are related to transportation. The Vehicle Technology Office recently offered $50 million for research projects that explore ways to lower cost and increase efficiency of plug-in electric vehicle components.

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[32] U.S. Department of Transportation. "FY2012 Clean Fuels Grant Program." http://www.fta.dot.gov/grants_14835.html. Accessed May 28, 2013.
[33] U.S. Department of Energy, Alternative Fuels Data Center. "Congestion Mitigation and Air Quality (CMAQ) Improvement Program." http://www.afdc.energy.gov/laws/law/US/284. Accessed May 2, 2013.
[34] U.S. Department of Transportation. "Congestion Mitigation and Air Quality Improvement Photo Library." December 6, 2012. http://www.fhwa.dot.gov/environment/air_quality/cmaq/reference/photo_library/index.cfm.
[35] Federal Register. "Notice of Funding Availability for the Department of Transportation's National Infrastructure Investments Under the Consolidated and Further Continuing Appropriations Act, 2013." April 26, 2013. https://www.federalregister.gov/articles/2013/04/26/2013-09889/notice-of-funding-availability-for-the-department-of-transportations-national-infrastructure#h-13.
[36] U.S.Department of Transportation. "TIGER 2012 Awards." http://www.dot.gov/sites/dot.dev/files/docs/fy2012tiger_0.pdf. Accessed May 28, 2013.

*High Occupancy Vehicle (HOV) Lane Exemption:* The U.S. Environmental Protection Agency (EPA) provides an exemption for single occupant low emission vehicles to operate in the HOV lane. Vehicles must be certified by the EPA and labeled. HOV access has been a popular incentive for sales of PEVs in some states. The exemption ends in 2017.[37]

Tax Credits

*Alternative Fuel Infrastructure Tax Credit*: A tax credit for fueling equipment, including natural gas fueling and EV charging stations ended December 31, 2013. There has been talk of reviving this credit but to date, no legislative action has been taken.

*Excise Tax Credit:* Another credit that expired at the end of 2013 is the excise tax credit of $0.50 per gasoline gallon equivalent for compressed natural gas and other liquid or gaseous motor fuels.

*Alternative Fuel Tax Exemption:* Certain uses of alternative fuels are exempt from federal fuel taxes. Exempt uses include some intercity and local buses, school buses, and use by a state or political subdivision of a state.[38] Compressed natural gas is normally taxed at rate of $0.183 per gasoline gallon equivalent (GGE); the uses noted above may be exempt from this tax.[39]

## 14. Resources

As noted throughout this report, there are some excellent web-based resources for learning about CNG and LNG vehicles and infrastructure. These sources can help those considering one of these fuels make informed decisions and avoid pitfalls. The primary sources used in preparing this report are listed here for convenience.

The federal government's **Alternative Fuel Data Center (http://www.afdc.energy.gov)** is a comprehensive one-stop shop for learning about alternative fuels basics, available vehicles, funded projects, best practices and funding opportunities. Some highlights of the AFDC include:

- Technology basics
- Nationwide fueling station locations for NGVs, plug-in electric vehicles and many other fuels
- Buying guides to alternative fuel light-, medium- and heavy-duty vehicles
- Fuel Cost Calculators
- Vehicle Cost Calculators
- Infrastructure Costs Calculators
- Case Studies of fleets that have converted http://energy.gov/public-services/vehicles/clean-cities

[37] http://www.afdc.energy.gov/laws/laws/US/tech/3253
[38] U.S. Internal Revenue Service. "Publication 510, Excise Taxes." Page 12. July 2012. http://www.irs.gov/pub/irs-pdf/p510.pdf.
[39] U.S. Internal Revenue Service. "Form 720, Quarterly Federal Excise Tax Return." Page 1. January 2013. http://www.irs.gov/pub/irs-pdf/f720.pdf.

- Video vignettes

The Department of Energy tracks federal, state and regional incentives through the Incentives web page at **http://www.afdc.energy.gov/laws/.** Also, agency websites will typically list funding opportunities. Many agencies have email lists to keep potential partners up to date on grants. Federal grants are listed on grants.gov, which can be searched by agency or by topic. Most grant programs offer funds once a year through competitive solicitations.

Department of Energy Programs:

*Clean Cities*: Clean Cities is a national network of local coalitions with some 18,000 stakeholders. These coalitions include public and private entities to deploy alternative fuels and other transportation energy and emission improvements. The Department of Energy Clean Cities program began in 1993 with a handful of cities. Clean Cities designees were required to demonstrate a coalition of public and private sector partners; vehicle manufacturers, infrastructure providers, governments, utilities and local businesses. Today, as the Clean Cities program celebrates its 20th anniversary, there are nearly 100 coalitions around the country. DOE has provided substantial funding for Clean Cities readiness planning, vehicle purchases and infrastructure. Clean Cities groups are effective advocates for alternative fuels and provide much valuable data such as the Quarterly Fuel Price report.

Clean Cities funding has helped bring more than 660,000 alternative fuel vehicles on to the road. Most of these were ethanol, but about 50,000 were NGVs. Approximately 1,000 CNG stations have received at least some funding through Clean Cities [40] The best way to find out about Clean Cities opportunities is to contact a local coalition; DOE provides a locator at http://www1.eere.energy.gov/cleancities/coalitions.html.

## 15. Conclusion

Designing, procuring, installing and operating a natural gas or liquefied natural gas infrastructure can be a complex and intimidating experience for fleet managers and other end users. However, there are many tools available to help businesses and government agencies make the right choices, including calculators and return on investment models, research reports and pragmatic guides to permitting CNG or LNG infrastructure. The goal of this report is to provide current or future CNG users with links to the available resources so that they can make informed and cost-effective choices.

[40] U.S. Department of Energy. "Clean Cities Goals and Accomplishments." http://www1.eere.energy.gov/cleancities/accomplishments.html.

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4. U.S. and Canadian Natural Gas Vehicle Market Analysis, Compressed Natural Gas Infrastructure, Final Report TIAX, prepared for America's Natural Gas Alliance, America's Natural Gas Alliance (ANGA), estimated date of publication 2013.
5. CNG Infrastructure Guide for the Prospective CNG Developer, Prepared by the Drive Natural Gas Initiative, America's Natural Gas Alliance, America's Natural Gas Alliance (ANGA), estimated date of publication 2013.
6. Herbert Burnett, Slide Presentations, South Coast Air Quality Management District Alternative Fuel Workshop, 2001
7. NFPA 52 Vehicular Gaseous Fuel Systems Code, 2013 Edition
8. Natural Gas Vehicle Training Institute (NGVI) CNG Fueling Station Design Training, 2013

# APPENDIX A

## CNG AND LNG INFRASTRUCTURE COMPONENTS AND MANUFACTURERS

| | Compressor System | Dispensing System | Dryers/Filters | Fuel Metering and Measurement Valves | Stationery Storage | Complete Fueling Station manuf/ packager | owner operator | turnkey fueling station provider |
|---|---|---|---|---|---|---|---|---|
| ACE Solutions, Inc. | | | | | | X | | X |
| Advanced Fuel Systems | | | | | | X | | X |
| Agility Fuel Systems | | X | | X | X | | | |
| Air & Gas Technologies | X | X | X | X | X | X | X | X |
| American Natural Gas Solutions | | | | | | X | X | X |
| ANGI International, LLC | X | X | X | X | X | X | | X |
| Applied LNG Technologies USA, LLC | | | | | | | X | |
| Aspro | X | X | X | | X | | | X |
| Atlas Copco Compressors LLC | X | X | X | X | X | | | X |
| AVSG LP | | | | | | X | | X |
| Bauer Compressors Inc. | X | | | | | | | |
| BLU/CH4 Energy | | | | | | | X | |
| Carbon Cutter Transport | X | | | | | | | |
| Celadon Energy Services | X | X | | | | | | X |
| Chart Industries | | X | | | X | X | | |
| Clean Energy Fuels Corp. | | | | | | X | X | X |
| CNG Source, Inc. | X | X | X | X | X | X | X | X |
| COBHAM | | | | | X | | | |
| CP Industries | | | | | X | | | |
| CUBOGAS | X | | | | X | X | | X |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Enviro Express Natural Gas, LLC | | | | | | | X | |
| ET Environmental | | | | | | | | |
| Faber Industrie S.p.A. | | | | | | | | |
| Ferus LNG | | | | | | | | |
| Flagship NGV | | | | | | | | |
| Fuel Solutions | | | | | | | | |
| GAIN Clean Fuel | X | X | | | | X | X | X |
| GNC Galileo | X | [41] | | | | | | |
| GP Strategies Corporation | | | | | | X | | X |
| Hunt, Guillot & Associates | | | | | | | | X |
| IGS Energy CNG Services | | | | | | | X | X |
| IMPCO Technologies | X | | | | | | | |
| IMW Industries Ltd. | X | X | X | X | X | X | | X |
| J-W Energy | X | | | X | | | | |
| Kakco LLC | | | | | | | X | X |
| Knox Wester | X | | | | | | X | X |
| Kraus Global Inc. | X | X | X | X | X | X | | |
| Mansfield Energy Partners | | | | | | | X | |
| Mainsfield Gas Equipment Systems | X | X | X | X | X | X | X | X |
| Metropolitan Utility District (Omaha) | | | | | | | | |
| Micro-Design, Inc. | X | X | | X | X | X | X | X |
| NatGasCar | | | | | | X | | |
| Northville | | | | | | | X | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Natural Gas | | | | | | | | |
| NGV Solutions, LLC | | | | | | X | X | X |
| Nuovo Energy Solutions | | | | | | X | | X |
| OPW Fueling Components | | X | | | | | | |
| Ozinga Energy, LLC | | | | | | | X | X |
| P.C. McKenzie | X | | | | | X | | |
| PowerFuel CNG Systems | | | | | | | X | X |
| PSB Industries | | X | | | | | | |
| Ratermann Manufacturing, Inc. | | | | X | | | | |
| Ryder Fleet Management Solutions | | | | | | | X | |
| Saybr Contractors, Inc. | | | | | | | | X |
| Siemens | | | | | | | | X |
| Swagelok Co. | X | X | X | X | X | | | |
| Trillium CNG | | | | | | X | X | X |
| Tulsa Gas Technologies | | | | X | | | | |
| VNG.Co | | | | | | | X | |
| Xebec | | | X | | | | | |

APPENDIX B: SUMMARY OF CODES APPLICABLE TO CNG STATIONS

| Code Agency/Organization | Primary Function |
|---|---|
| ANSI | Facilitates the development of certain codes and standards that govern the use of CNG and the manufacturing of CNG fueling components, including nozzles, receptacles, dispensers, hoses, breakaway devices, valves, and other related fueling components |
| ASME<br>• Boiler and Pressure Vessel Code Section 8<br>• ANSI/ASME B31.3 Chemical Plant and Conventional fuel Refining Piping | Regulates high-pressure CNG storage vessels and piping<br>• Section 8 is the manufacturing standard for the pressure vessels used in the CNG station<br>B31.3 establishes the specifications for the piping throughout the CNG station |
| ASNT | Tests components for safety |
| NEMA | Establish standards for electrical component manufacturing |
| NFPA<br>• NFPA 52<br>• NFPA 70<br>• NFPA 30A | Regulates the use of natural gas as a vehicle fuel, including stations and vehicles<br>• Defines the boundaries of the hazardous areas inside the fueling station<br>• Establishes the NEC<br>• Governs the use of multiple fuels in one location |
| NFPA 70/NEC | Defines the electrical classification of the hazardous areas within a CNG station |
| OSHA | Regulates occupational safety and health in the work environment |
| SAE | J1616 establishes the recommended practice for fuel quality and water content |
| UBC, Local Jurisdiction | Regulates structures that contain CNG fueling equipment |
| UFC | Some states and/or localities use this code; often contains NFPA 52 within it |
| UPC | Governs the plumbing components of CNG stations |
| NIST | Establishes the unit of measurement for custody transfer of CNG from the retailer to the customer |
| UL | Tests components and publishes lists according to compliance |

Source: CNG Infrastructure Guide prepared by TIAX for America's Natural Gas Alliance, 2012

# APPENDIX C: SPREADSHEET TOOLS